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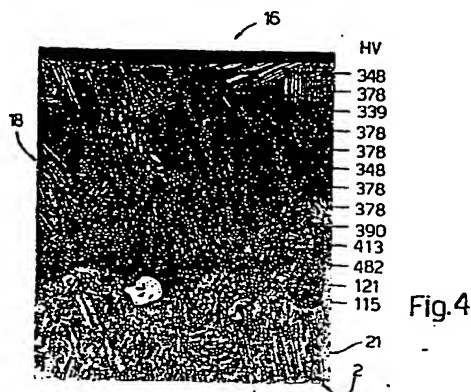
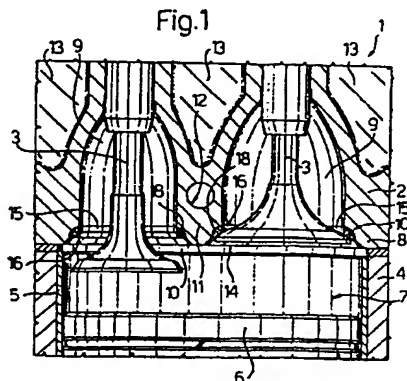
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54 Method for forming a valve seat on an endothermic engine cylinder head, and the engine with valve seats formed by this method.

57 The method consists of depositing an added material in a compartment (15) of an engine cylinder head (2) which is constructed of a base material different from the added material and able to form therewith an alloy having a relatively high hardness and strength; then by means of a laser beam heating the added layer (21) of base material have

been melted in order to produce alloying of the added material in this latter; and finally cooling the molten metal alloy thus formed in the compartment (15) in order to produce its rapid solidification therein.



METHOD FOR FORMING A VALVE SEAT ON AN ENDOTHERMIC ENGINE CYLINDER HEAD, AND THE ENGINE WITH VALVE SEATS FORMED BY THIS METHOD

This invention relates to a method for forming a valve seat on an endothermic engine cylinder head, and to a valve seat formed by this method. The present invention also relates to an endothermic engine comprising valve seats formed by this method.

In most of the current endothermic engines, the seats for the engine intake and exhaust valves are formed in inserts constructed of alloys of high resistance to wear and oxidation, and driven into suitable compartments provided in the engine cylinder head. This constructional method is used particularly in engines of light alloy construction, in which said inserts are constructed of cast iron and are cold-driven into the cylinder head.

The described constructional method is not without drawbacks. Specifically, a notching effect is produced in the cylinder head at the edges of the insert carrying the valve seat. This drawback is serious, in that it produces high localised stresses in the cylinder head. Furthermore, because of the size of the inserts and their housing compartments formed in the cylinder head, the dimensions of the bridge (the cylinder head element lying between two adjacent valve seats) must be small, so weakening the cylinder head and requiring the cylinder head cooling ducts to be withdrawn from that head surface facing the engine cylinders, so increasing the thermal stresses acting on the cylinder head.

The object of the present invention is to provide a method for forming valve seats in an endothermic engine cylinder head of light alloy construction, which disposes of the presence of said inserts therein and thus obviates the described drawbacks. A

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further object of the present invention is to provide an endothermic engine of light alloy construction provided with valve seats free from the described drawbacks.

The aforesaid objects are attained according to the present invention by a method for forming a valve seat on an endothermic engine head of light alloy construction, characterised by comprising the following stages:

- depositing an added material in a compartment provided in said cylinder head in the position which said valve seat is to occupy, said cylinder head being constructed of a base metal different from said added material and able to form therewith alloys capable of assuming strength and hardness characteristics superior to those of the base metal;

- heating said added material by a laser beam of predetermined power focused on said compartment until melting takes place of said added material in said compartment and of a layer of predetermined thickness of the base material which immediately surrounds this latter;

- maintaining the molten state of said added material and said layer of base material by said laser beam for a time sufficient to enable the former to diffuse into the latter and vice-versa, so as to form an alloy in the molten state in said compartment; and

- cooling said alloy in the molten state contained in said compartment in order to cause its rapid solidification therein.

The present invention also relates to an endothermic engine comprising a cylinder head of light alloy construction provided with a plurality of valve seats for the engine intake and exhaust, characterised in that each of said valve seats comprises a

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substantially circular bore bounded by a flared edge, and an annular coating of predetermined thickness which coats said edge, said coating being constructed of a metal alloy between a base material of which said cylinder head is constructed and an added material which has been alloyed with said base material by localised heating effected by a laser beam, in such a manner that said coating, which has hardness and strength characteristics superior to those of said base material, forms a single piece with said cylinder head.

Further objects and advantages of the present invention will be apparent from the description given hereinafter of a non-limiting embodiment thereof, with reference to the accompanying drawings in which:

Figure 1 is a diagrammatic cross-section through an endothermic engine, of which the cylinder head is provided with valve seats formed by the method of the present invention;

Figure 2 is a diagrammatic plan view of an endothermic engine cylinder head constructed in accordance with the present invention;

Figures 3 and 4 are two micrographs of an endothermic engine cylinder head after two different stages of the method of the invention; and

Figure 5 is a schematic diagram relative to the method of the present invention.

In Figures 1 and 2, the reference numeral 1 indicates overall an endothermic engine which in the illustrated example is a compression ignition engine, or diesel engine. The engine 1 comprises a cylinder head 2 carrying a plurality of intake and exhaust valves 3 for the engine 1, and a cylinder block 4

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comprising a plurality of cylinders 5 defining, together with the respective pistons 6 slidable therein, combustion chambers 7 which are closed towards the valves 3 by a base wall 8 of the cylinder head 2. This latter is provided with housings 9 for the valves 3, and seal seats 10 therefor provided in the wall 8. The housings 9 and the relative seal seats 10 of each pair of valves 3 disposed in any one cylinder 5 are divided by a portion 11 of the cylinder head 2 known technically as the bridge. The portion or bridge 11 is provided with a cooling duct 12 (Ricardo duct) for cooling the seats 10 of the valves 3. The cylinder head 2 is also provided with cooling ducts 13. The ducts 12 and 13 are disposed at predetermined distances from a surface 14 of the wall 8 which faces the chamber 7 and is thus exposed directly to the heat of combustion, and they serve to maintain the temperature of the cylinder head 2 within acceptable limits.

The cylinder head 2 and base 4 are constructed of any suitable light alloy, for example an aluminium-based light alloy. In all cases the seats 10 must have a hardness and resistance to wear and oxidation which are superior to those of the constituent alloy of the cylinder head 2, because, together with the bridge 11, they represent the most highly stressed regions of the cylinder head 2.

Consequently, each seat 10 comprises a substantially circular compartment or bore 15 which passes through the wall 8 and is bounded by a flared edge 16 and an annular coating 18 of predetermined thickness which coats the edge 16 and is formed as a single piece with the cylinder head 2. In this respect, the coating 18, which has hardness and strength characteristics superior to those of the base metal material of which the

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cylinder head 2 is constructed, is formed by alloying with said base material an added material able to form an alloy with the base material in the manner described hereinafter, using a laser beam produced by any power laser apparatus of known type. Said added material can be any metal, ceramic or metallo-ceramic material able to form with the base material an alloy having strength and hardness characteristics superior to those thereof. The base material is constituted substantially by aluminium, and the added material can be any of a whole series of metal or ceramic materials such as nickel powders, nickel-chrome powders, Eatonite powders (the commercial name of an alloy containing carbon, silicon, iron, chromium and mainly nickel), steel powders (of the molybdenum or maraging type), or nickel or chromium powders mixed with oxides. The powders can be deposited on the edge 16 in the form of paste, or by any other method. Alternatively, they can be applied in the form of sintered or prefused foils.

A method is described hereinafter by way of example for forming the aforesaid valve seats 10 in the particular case in which the cylinder head 2 is of light alloy construction, the base material being aluminium and the added material being in the form of iron-based alloys (maraging steels) and/or nickel.

The composition of these added alloys is substantially as follows. Iron-based alloys: chromium content 5-20%; molybdenum content 3-18%; carbon content 0.2-3%; remainder iron and minimum percentages of other elements. Nickel-based alloys: chromium content 5-20%; iron content 1-5%; carbon content 0.2-1%; remainder nickel and minimum percentages of other elements.

With reference to Figure 3, which shows a micrograph of a

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portion of the cylinder head 3 surrounding the bore or compartment 15, in order to form a seat 10 such as that described on the cylinder head 2, an annular layer 19 of predetermined thickness of an added material 20, which in this case mainly contains iron, is firstly applied over the entire edge 16 of each compartment 15.

The thickness of the layer 19 is substantially uniform and lies between 0.1 and 1 millimetre, and is preferably about 0.5 millimetres. The layer 19 can be applied to the edge 16 in various ways according to the composition and consistency of the material 20. In the case illustrated in Figure 3, the layer 19 is solid and compact, in that the material 20 has been deposited by a plasma spray depositing method. This method is well known and consists of atomising the added material 20, constituted by a powder or solid wire, into a jet of gas heated to high temperature, and projecting the plasma spray obtained in this manner onto the surface of the edge 16 via a suitable tube so as to deposit the material 20 in the fluid state onto the relatively cold edge 16, and consequently cause it to rapidly solidify to obtain the layer 19.

According to a modification, not illustrated, the layer 19 can be deposited by extrusion, using a suitable device, or manually by means of a spatula. In this case, the added material 20 is in the form of a metal powder which is mixed with a solvent in order to obtain a paste, or a fluid substance of high viscosity having gel consistency. This paste is then deposited on the edge 16 to form the layer 19.

According to a further modification, not shown, the layer 19 is in the form of a metal foil of maraging steel, possibly obtained

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by sintering, and simply deposited in contact with the surface of the edge 16.

Of the three described systems for forming the layer 19, the preferred is the first, i.e. plasma spray depositing, both because this method creates adhesion between the added material 20 and the base material of the cylinder head 2, and because it destroys the thin oxide layer ( $\text{Al}_2\text{O}_3$ ) present on the edge 16 of the aluminium cylinder head 2, and which is detrimental to the alloying.

After forming the layer 19, the cylinder head 2 is disposed in a working station, not shown, of a power laser apparatus, not shown. In this, using known methods and systems, a laser beam of predetermined power, preferably between 6 and 12 kilowatts, is focused onto the edge 16 of the compartment 15 in a position corresponding with the layer 19. The laser beam is projected onto the cylinder head 2 by a known scanning device, not shown, which moves at predeterminable speed so as to move said laser beam along the edge 16 of the compartment or bore 15 in an annular trajectory at a speed of between 10 and 50 cm/minute.

The laser beam power is also adjusted in accordance with the irradiated area so as to obtain on the cylinder head 2 a specific laser beam power of between 180 and 300 joules/ $\text{mm}^2$ , i.e. the cylinder head 2 is irradiated in such a manner as to transmit to it a thermal energy of between 180 and 300 joules for each  $\text{mm}^2$  of surface irradiated by the laser beam. In this manner, the high-melting layer 19 (melting point between 1000 and 1400°C) can be melted together with part of the underlying base material, which is not directly irradiated but is low-melting (660°C).

In this respect, on striking the layer 19, the laser beam



rapidly heats the material 20 by radiation, and the heat is transmitted by conduction to the cylinder head 2, thus also heating a layer of determined thickness of the base material which immediately surrounds the compartment or bore 15. The laser heating is protracted for a time sufficient for melting all the material 20 of the layer 19 together with the said underlying layer of base material, and to allow diffusion of the former into the latter and vice-versa, so as to form a metal alloy in the substantially liquid state in the compartment or bore 15. Finally, the laser beam is suppressed, and the cylinder head 2 is allowed to cool in free air. The high thermal capacity of the cylinder head 2 produces rapid cooling of the metal alloy which has just been formed, so as to cause it to rapidly solidify within the compartment 15, to form the coating 18.

In Figure 4, which illustrates a micrograph of a portion of a valve seat 10 formed by the described method, the metallo-graphic aspect of the darker coating 18 can be clearly seen, its composition corresponding approximately to that of the compound  $\text{Fe Al}_3$  (35-40% of iron in aluminium). A layer 21 of remelted base material (aluminium) is present immediately below the coating 18, and finally the base material of the cylinder head 2 which has not been altered by the surface thermal treatment undergone by the cylinder head 2 can be seen on the bottom right. The obtained Vickers hardness values are shown to the side of the micrograph. As can be seen, immediately in front of the layer 21 (HV 115-121  $\text{Kg/mm}^2$ ) there is present a layer of coating 18 having a higher hardness (HV 482-413  $\text{Kg/mm}^2$ ) than the average hardness of the coating 18 (HV 378  $\text{Kg/mm}^2$ ). This is due to the fact that the

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added material 20, of higher density than the base material, melts into this latter when both are in the liquid state, and consequently the coating 18 is richer in the added material 20 towards the layer 21, whereas at the surface it is richer in aluminium (its base material) and thus more tender. This situation improves the anchoring of the coating 18, which having been formed by direct alloying of the material 20 on the cylinder head 2, forms a single piece with this latter.

Figure 5 shows by way of example a diagram of the laser parameters, in which the shaded portion illustrates the optimum working region within which the point of intersection of the abscissa representing the laser beam scanning velocity and the ordinate representing the laser beam power must fall in order to obtain best results.

The advantages of the present invention are apparent from the description. By means of a simple and rapid surface alloying operation, it enables valve seats to be formed which are in one piece with the engine cylinder head but have superior mechanical characteristics (in the illustrated example, the hardness of the cylinder head base material was only 77 Vickers). This means that hard material inserts do not need to be mounted in the cylinder head, thus obviating the weakening of the cylinder head caused by the need to provide the insert seats therein, and by the notching effect produced by these on the cylinder head itself. Furthermore, the valve seats formed by the method of the invention are of small overall size, and thus enable the bridge between one valve and the next to be of greater dimensions, and consequently stronger, so

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enabling the cooling ducts to be brought closer to the explosion chamber and reduce the thermal stresses on the valve seats and on the cylinder head.

From the description it is apparent that modifications can be made to the present invention without leaving its scope.

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## PATENT CLAIMS

1. A method for forming a valve seat (10) on a cylinder head (2) of an endothermic engine (1) of light alloy construction, characterised by comprising the following stages:

- depositing an added material (20) in a compartment (15) provided in said cylinder head (2) in the position which said valve seat (10) is to occupy, said cylinder head (2) being constructed of a base metal different from said added material (20) and able to form therewith alloys capable of assuming strength and hardness characteristics superior to those of the base metal;

- heating said added material (20) by a laser beam of predetermined power focused onto said compartment (15) until melting takes place of said added material (20) in said compartment (15) and of a layer of determined thickness of the base material which immediately surrounds this latter;

- maintaining the molten state of said added material (20) and said layer of base material by said laser beam for a time sufficient to enable the former to diffuse into the latter and vice-versa, so as to form an alloy in the molten state in said compartment (15); and

- cooling said alloy in the molten state contained in said compartment (15) in order to cause its rapid solidification therein.

2. A method as claimed in claim 1, characterised in that said laser beam has a power of between 6 and 12 kilowatts.

3. A method as claimed in claim 1 or 2, characterised in that said laser beam is projected by a scanning device which moves in such a manner as to move said laser beam along said compartment at a

speed of between 10 and 50 cm/minute.

4. A method as claimed in one of the preceding claims, characterised in that said compartment is constituted by a bore (15) provided in a wall (8) of said cylinder head (2) and bounded by a flared edge (16), said added material (20) being disposed along said edge (16) in such a manner as to form an annular layer (19) of predetermined thickness.

5. A method as claimed in claim 4, characterised in that said thickness of said annular layer (19) of added material (20) lies between 0.1 and 1 mm and is preferably 0.5 mm.

6. A method as claimed in one of the preceding claims, characterised in that said added material (20) is constituted by a powder mixed with a solvent to form a paste.

7. A method as claimed in one of claims 1 to 5, characterised in that said added material (20) is deposited in said compartment (15) by a plasma spray method, so as to coat said compartment (15) with a solid compact layer (19).

8. A method as claimed in one of the preceding claims, characterised in that cylinder head (2) is of light alloy construction, said base material being substantially aluminium.

9. A method as claimed in claim 8, characterised in that said added material (20) mainly contains iron.

10. A method as claimed in claim 8, characterised in that said added material (20) mainly contains nickel.

11. A method as claimed in one of the preceding claims, characterised in that the rapid solidification of said alloy is effected by suppressing said laser beam and allowing cooling in free air

12. A method as claimed in any one of the preceding claims, characterised in that the specific power discharged by said laser

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beam onto said cylinder head (2) lies between 180 and 300 joules/mm<sup>2</sup>.

13. An endothermic engine (1) comprising a cylinder head (2) of light alloy construction provided with a plurality of valve seats (10) for the intake and exhaust of said engine (1), characterised in that each of said valve seats (10) comprises a substantially circular bore (15) bounded by a flared edge (16), and an annular coating (18) of predetermined thickness which coats said edge (16), said coating (18) being constructed of a metal alloy between the base material of which said cylinder head (2) is constructed and an added material (20) which has been alloyed with said base material by localised heating effected by a laser beam, in such a manner that said coating (18), which has hardness and strength characteristics superior to those of said base metal, forms a single piece with said cylinder head (2).

Prof. Ing. BONGIOVANNI Guido

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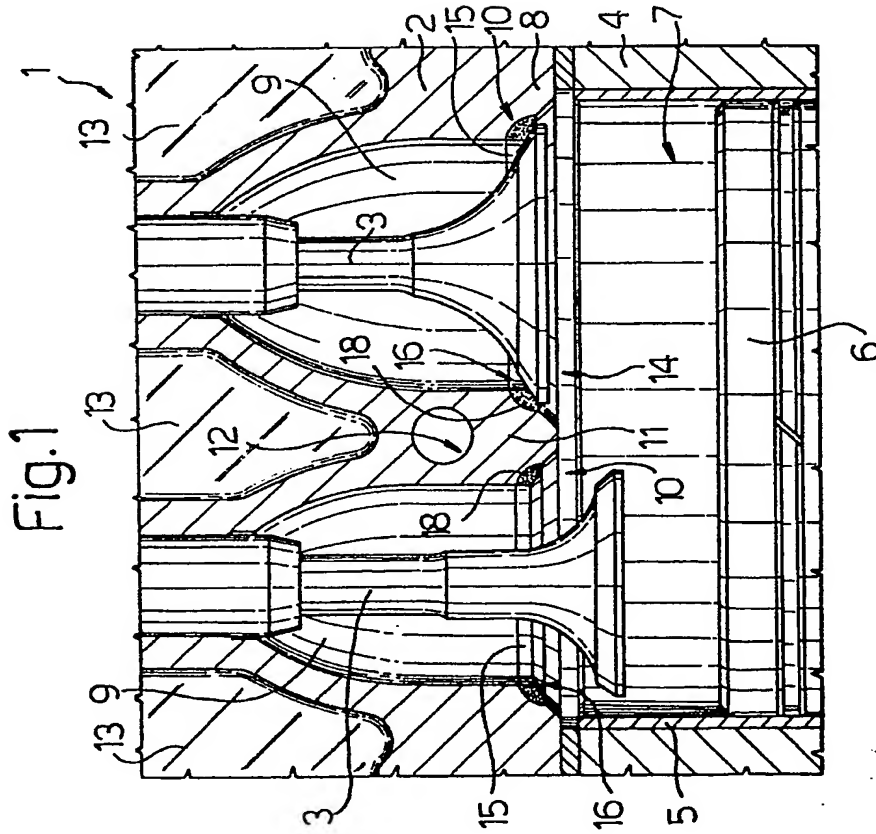


Fig. 1

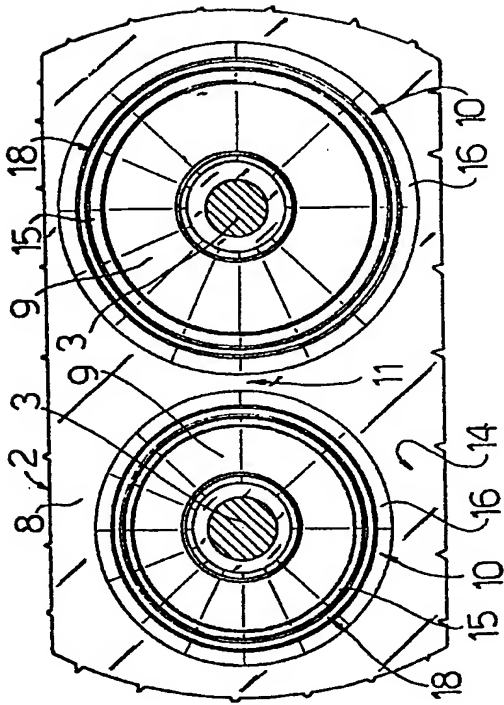


Fig. 2

$$\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2}$$

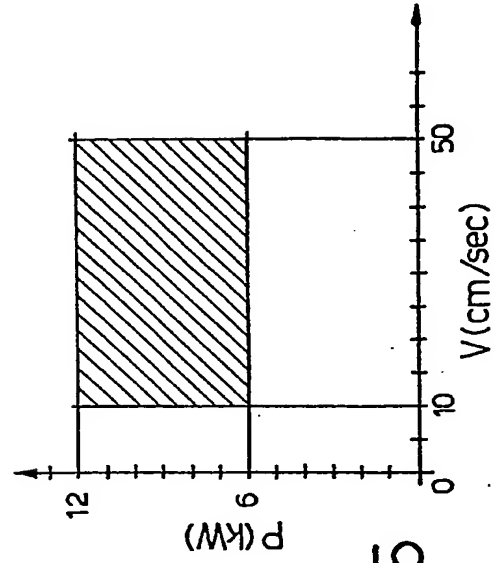


Fig. 5

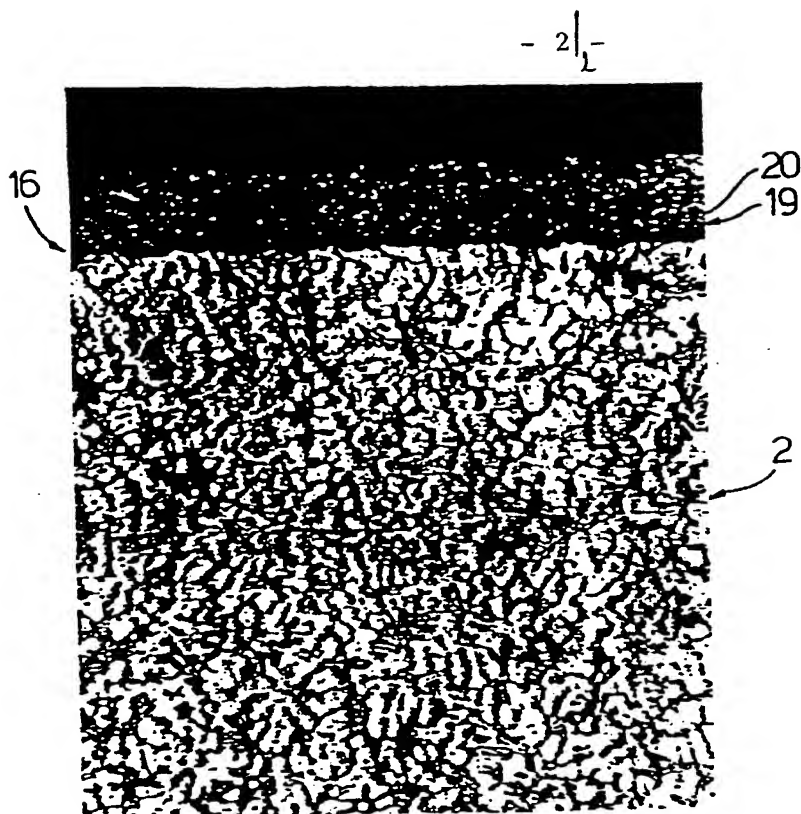


Fig. 3

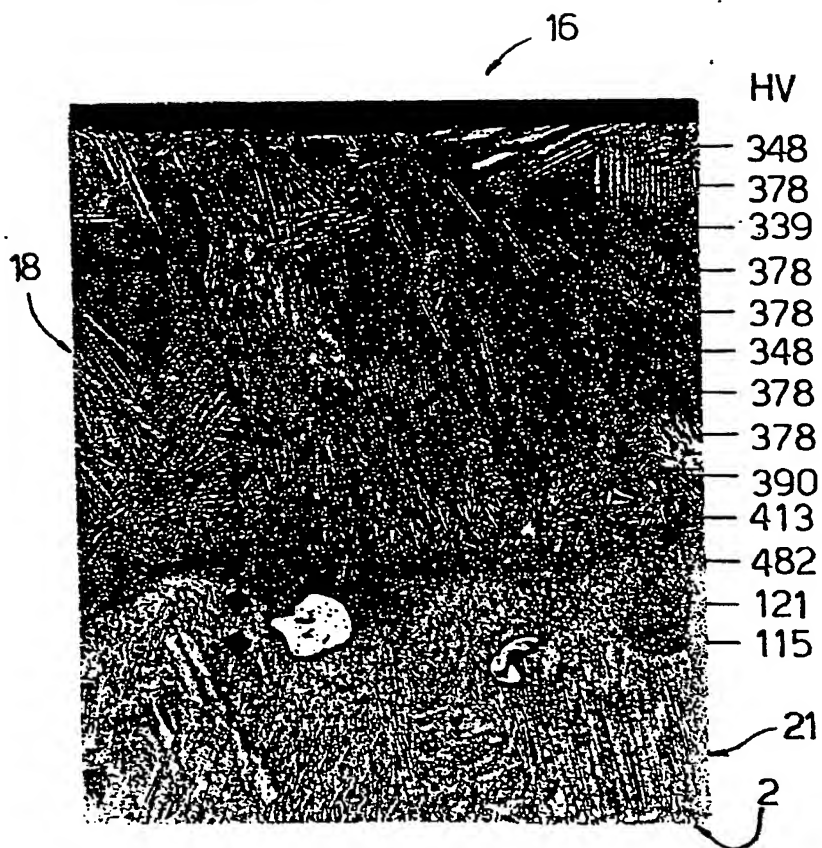


Fig. 4





European Patent  
Office

# EUROPEAN SEARCH REPORT

0092683

Application number

EP 83 10 3005

DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl. 7)
Y	US-A-3 505 489 (HITACHI METALS)  * Whole document *	1, 2, 4, 10, 13	F 01 L 3/22 C 23 C 1/00
Y	FR-A-2 452 528 (ROLLS-ROYCE)  * Whole document *	1, 3, 5, 7, 10, 13	
A	FR-A-1 129 024 (A.I. LATIL)  * Page 1, line 1 - right-hand column, paragraph 5; page 2, left-hand column, paragraph 9 - right-hand column, paragraph 3 *	1, 11, 13	
A	FR-A-2 430 286 (C.R. FIAT)  * Page 3, lines 1-13; page 6, line 15 - page 7, line 19; page 8, line 20 - page 9, line 10; figures 1, 2 *	1-3, 5, 6, 13	TECHNICAL FIELDS SEARCHED (Int. Cl. 7)  F 01 L C 23 C F 02 B
A	FR-A-2 165 646 (DAIMLER-BENZ) * Page 2, lines 18-20 *	8, 9	
A	GB-A- 475 585 (WILCOX) * Page 1, lines 40-61 *	9, 10	
The present search report has been drawn up for all claims			
Place of search THE HAGUE		Date of completion of the search 03-08-1983	Examiner VON ARX H.P.
<b>CATEGORY OF CITED DOCUMENTS</b>			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document		T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons  & : member of the same patent family, corresponding document	

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